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DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Mercury Vapor Discharge Lamp and Pressure Regulating Means therefor

We, WESTINGHOUSE ELECTRIC CORPORATION, of Three Gateway Center, Pittsburgh 30, Pennsylvania, United States of America, a corporation organized and existing under the laws of the Commonwealth of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to mercury vapor discharge lamps and has particular reference to an improved mercury vapor discharge lamp having a mercury-vapour pressure regulating means that permits the lamp to be operated efficiently at high power loadings or under a wide range of ambient temperatures, or both.

As is well known, the efficiency of a fluorescent lamp is at a maximum when the mercury vapor pressure within the lamp is maintained at approximately 6 to 10 microns. At this vapor pressure, the amount of 2537 A radiation produced by the discharge is at a maximum. In fluorescent lamps of conventional loading the design parameters are so correlated that the required mercury vapor pressure prevails under normal operating conditions. However, when the lamp is operated at higher power loadings or under high ambient temperature conditions, the mercury vapor pressure increases and the light output drops off sharply.

In one type of highly-loaded fluorescent lamp now being marketed, this basic problem is partially solved by mounting a heat deflecting shield on one (or both) of the lamp stems to provide a cool region within the lamp that maintains the mercury vapor pressure at the proper value. Highly-loaded lamps utilizing a shielded or relatively cool region as the mercury-vapor control center, however, provide only a partial answer to the problem since their light output is dependent upon and greatly influenced by ambient temperature conditions. Thus, when a conventional highly-loaded fluorescent lamp is operated in a semi-enclosed or totally enclosed fixture, the mercury vapor pressure increases to such a value that a marked decrease in the light output and efficiency results. In addition, since the temperature of the cool region within the lamp is also dependent upon lamp loading, this approach to the problem places a limit on the loading that can be used.

In order to avoid these limitations, it has been proposed that the mercury vapor pressure within a fluorescent lamp be controlled by an amalgam of a selected metal and mercury. Since the vapor pressure of mercury is lower in the case of a mercury amalgam than it is for pure mercury, the use of such an amalgam affords the distinct advantage of controlling the mercury vapor pressure within the lamp without resorting to end chambers or the like. Such an amalgam-containing fluorescent lamp is disclosed in British Patent No. 923,890. While this approach afforded many advantages, it presented rather serious manufacturing problems in that the amalgam had to be coated over a rather large surface area and could not be placed near the electrodes, as indicated in the aforesaid patent. In addition, the amalgam contained relatively large amounts of mercury and thus had a tendency to melt and migrate from the desired location within the lamp during the later stages of lamp manufacture and during operation under extremely high ambient temperature conditons.

It is accordingly the general object of the present invention to avoid the foregoing and

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other problems associated with the use of an amalgam as a mercury-vapour control means in a gaseous discharge lamp.

Another and more specific object is the provision of an improved fluorescent lamp that can be operated at high loadings and over a wide range of ambient temperatures with a minimum loss of light output.

An additional object is the provision of an amalgam-containing fluorescent lamp that can be conveniently manufactured on a mass production basis.

Still another object is the provision of a novel mercury-vapor control assembly for an electric discharge lamp utilizing an amalgam-forming metal.

A further object is the provision of a method for manufacturing such mercury-vapor control assemblies on a mass production basis.

The foregoing objects, and other advantages, which will become apparent as the description proceeds, are achieved according to the invention by utilizing a relatively small amount of amalgam and placing it at a selected localized region within the lamp such that it will operate at the temperature required to maintain the desired mercury vapor pressure. The amalgam is held in the proper location within the lamp by a support assembly that is attached to one (or both) of the stems or to the envelope while the lamp is being fabricated.

According to a preferred embodiment, the amalgam-forming metal is sandwiched between two strips of wire cloth. The cloth is made from a metal that the amalgam will wet and the openings in the cloth are such that the amalgam, even when in a liquid state, will be retained within the cloth matrix by capillary action. The metal-cloth sandwich when placed within the lamp does not contain any mercury. The amalgam is formed after the lamp has been dosed with a predetermined amount of mercury in the regular fashion.

Another important feature of the invention resides in maintaining a critical balance between the mercury and parent-metal content of the amalgam. The amalgam composition is such that the amalgam will remain substantially in the solid phase when the lamp is not in use and will remain in a semi-liquid phase over practically the entire range of temperatures which prevail at the amalgam location when the lamp is operated. In a preferred embodiment, an indium-mercury amalgam is used and the atomic per cent indium is maintained within a selected critical range. Specifically, the amalgam contains from about 80 to about 95 atomic per cent indium. Surprisingly, this particular amalgam not only has the desired physical properties at the operating and non-operating temperatures but maintains the light output at higher levels over a wider range of operating temperatures. Lamps containing this particular amalgam will thus operate efficiently over a wide range of ambient temperatures and at loading significantly higher than those now used.

Various structures and assemblies for holding the amalgam in the desired location within the lamp are provided including one wherein a bimetallic element is utilized to compensate for temperature variations which may be encountered during lamp operation. A preferred method for fabricating a mercury-vapor control assembly utilizing strips of metal wire cloth, a strip of amalgam-forming metal, and a pair of rollers is also provided.

A better understanding of the invention will be obtained by referring to the accompanying drawings, wherein:

Figure 1 is a front elevational view of a highly-loaded fluorescent lamp embodying the present invention, portions of the bulb being removed for convenience of illustration;

Fig. 2 is an enlarged perspective view of the electrode mount structure of the aforesaid lamp that carries the vapor-pressure control assembly of the present invention;

Fig. 3 is a sectional view through the mount along the line III—III of Fig. 2.

Fig. 4 is an enlarged plan view of the laminated vapor-phase control assembly shown in Figs. 1—3, portions of the assembly being removed to indicate the various layers;

Fig. 5 is a perspective view of the clamp used to hold the aforesaid assembly in position on the stem;

Fig. 6 is a side view illustrating a preferred method for making the laminated cloth-metal assembly shown in Fig. 4;

Fig. 7 is an enlarged fragmentary view of the cloth-metal assembly produced by the method illustrated in Fig. 6;

Fig. 8 is a perspective view of another fluorescent lamp mount embodying an alternative form of vapor control assembly;

Fig. 9 is a plan view of the laminated cloth-metal component of the pressure control assembly shown in Fig. 8, portions of the various layers being omitted for illustrative purposes;

Figs. 10 to 21 are views illustrating alternative holding means and arrangements for mounting the mercury-vapor pressure control assembly within the desired location within the lamp;

Fig. 22 is a phase diagram of the mercury-indium alloy system indicating the preferred range of indium content in the amalgam according to the invention;

Fig. 23 is a graph illustrating the difference in the operating temperature of the amalgam when the latter is placed on the stem rather than on the bulb wall;

Fig. 24 is a graph comparing the brightness versus ambient temperature characteristics of a conventional highly-loaded fluorescent lamp having end chambers and an indium-mercy

amalgam lamp embodying the present invention;

Fig. 25 is a graph illustrating the improved brightness versus ambient temperature characteristics displayed by indium-mercury amalgam lamps containing increased amounts of indium;

Fig. 26 is a graph illustrating the brightness versus ambient temperature characteristics of a family of lamps having the amalgam mounted at different distances from the electrode in accordance with the invention; and

Fig. 27 is a graph contrasting the ambient-temperature range versus brightness-maintenance characteristics of the improved indium-mercury amalgam lamps of the present invention and conventional highly-loaded lamps in which the vapor pressure is controlled by the temperature of condensed mercury.

Embodiment of Figs. 1—4

Referring now to the drawings in detail, in Fig. 1 there is shown a highly-loaded fluorescent lamp 28 having a tubular light-transmitting envelope 29 which has the usual re-entrant mounts 30 sealed into each of its ends. Each of the mounts carries a thermionic electrode 32 that is connected by means of lead wires 34 and 34′ to recessed contacts housed within a suitable base 35 attached to each end of the envelope 29. The inner surface of the envelope is coated with a layer 33 of an ultraviolet-responsive phosphor and one of the mounts 30 is provided with a tubulation 36 that is tipped off in the usual manner after the lamp has been evacuated, mercury dosed and filled with a suitable inert starting gas such as argon, neon, or mixture thereof. In accordance with the preferred embodiment of the present invention, one of the mounts 30 (preferably the non-tubulated mount as shown in Fig. 1) is provided with a mercury-vapor pressure control structure such as an arcuate assembly 40 which includes an amalgam-forming metal and is fastened to the mount.

As is illustrated more clearly in Fig. 2, the mount 30 comprises the usual flared vitreous stem 31 and lead wires 34 and 34′ which support the electrode 32 and are sealed through a press 37 formed on one end of the stem. The electrode 32 preferably consists of a linear triple-coiled tungsten filament that carries the usual alkaline-earth oxide coating. A pair of enlarged metal electrode shields 38 and 38′ are also mounted on either side of and in parallel relationship with the electrode 32, preferably by attaching them to the ends of the lead wires.

As shown in Fig. 4, the mercury-vapor pressure control assembly 40 initially comprises a rectangular lamination consisting of a layer 44 of suitable amalgam forming metal sandwiched between two strips 42, 43 of metal wire mesh or cloth. The strips of wire cloth thus serve as a support structure or matrix for the amalgam-forming metal. As illustrated in Figs. 2 and 3, in accordance with this form of the invention the aforesaid laminated assembly 40 is wrapped around the cylindrical portion of the stem 31 and tightly clamped therearound by a resilient wire ring 41 (Fig. 5). The assembly is so positioned that the leading edge of the assembly is spaced a predetermined distance " d " from the transverse plane that passes through the intermediate segments of the lead wires 34, 34′ fastened to the ends of the electrode 32. In the case of a linear electrode of the type here shown, the aforesaid plane will of course also pass through the electrode.

The laminated assembly 40 when thus mounted on the stem 31 constitutes a collar that is readily and securely fastened directly to the electrode mount 30. To facilitate this operation, the length of the laminated assembly 40 may be made slightly less than the circumference of the stem 31 so that the ends of the assembly will be spaced from one another, as will be noted in Figs. 1 to 3.

The distance " d " between the leading edge of the collar assembly 40 and the electrode 32 (measured along a line parallel to the stem axis) is critical insofar as it determines the temperature at which the amalgam operates in the completed lamp. This, in turn, determines the mercury vapor pressure within the lamp when the latter is energized and thus controls its light output and operating efficiency.

Any metal which amalgamates readily with mercury and which will not contaminate the lamp atmosphere at the temperatures which will be encountered during the assembly and operation of the lamp can be used. Examples of metals which meet both of these requirements and are suitable include thallium, tin, and alloys thereof. Indium is particularly suitable, as hereinafter disclosed.

It should also be noted that the overlying strips 42 and 43 of cloth can be woven from other materials besides metal wire. It should, however, be fabricated from a material that is substantially inert with respect to both mercury and the amalgam-forming metal and should also be one which the amalgam will wet. The cloth can, accordingly, be made from glass or quartz fibers or from nickel, nickel plated iron, aluminum, titanium, or iron wire. Grade " A " nickel cloth has given excellent results and is preferred.

Any suitable foraminous material, such as perforated sheets of metal, can also be used in place of the cloth strips.

Method of Fabricating Vapor Control Assembly

In Fig. 6 there is shown a preferred method for fabricating the laminated vapor-pressure control assembly 40 described above. As shown, the preferred technique involves posi-

tioning a strip of a suitable amalgam-forming metal, such as indium, between two strips of foraminous material 42 and 43 (nickel wire cloth, for example, as indicated) and feeding the strips while in such overlying relationship between a pair of rollers 46 and 47 which rotate and compress the respective strips one against the other. Since the amalgam-forming strip 44 is very ductile and soft, the foraminous strips 42 and 43 are partly embedded in the strip 44. As a result, the overlying strips of foraminous material adhere to and are held together solely by the interposed layer of amalgam-forming metal thus providing a lamination 40 that can be readily handled without falling apart. This method of fabrication is very advantageous since continuous strips of material can be automatically fed into the rollers to produce a continuous lamination that can then be cut into the required lengths.

Mount and Lamp Assembly

After the lead wires, electrodes and anodes have been joined with the glass stem 31 in the usual well-known manner to form the mount 30, the laminated vapor-pressure control assembly 40 is simply wrapped around the stem and clamped in the proper position thereon by the wire ring 41, as described previously and shown in Figs. 2 and 3. If desired, the assembly and ring can be combined to form a unit that can be slipped into the stem. The amount 30 is then sealed into one end of the envelope 29 in the regular manner. When this operation is completed, the tubulated mount is sealed into the other end of the envelope which is then evacuated, charged with a suitable fill gas, dosed with a predetermined quantity of mercury and tipped off in accordance with standard lamp-making procedures. The mercury combines with the metal strip 44 in the tipped-off lamp to form an amalgam of the desired composition.

Since the vapor control assembly 40 is fastened to one of the mounts 30 before it is sealed into the envelope 29 and that this stage contains only the amalgam-forming metal 44, the lamp 28 can be manufactured in the conventional manner and no special precautions are necessary to protect the assembly from heat etc. during lamp manufacture as in the prior art lamps when the amalagam was formed prior to lamp assembly. The composition and physical properties of the amalgam that is subsequently formed within the completed lamp is determined by the quantities of mercury and amalgam-forming metal that are separately placed within the lamp as it is being fabricated. The amount of amalgam-forming metal is determined by the dimensions of the strip 44 that is placed in the laminated assembly 40, and the amount of mercury is regulated in the usual manner by the dosing operation.

The vapor-pressure control assembly 40 is preferably placed on the non-tubulated mount 30, as shown in Figs. 1 to 3, to avoid the accidental loss of amalgam-forming metal during lamp manufacture. Experience has shown that this can occur when the lamps are fabricated on a sealing machine of the type in which the tubulated mount is first sealed into the lower end of the envelope 29 while the latter is held in a vertical position, and the envelope is then inverted to seal the non-tubulated mount into the other end of the envelope. When the assembly 40 was attached to the tubulated mount, occasionally some of the heat-softened amalgam-forming metal would be torn free from the assembly as the envelope was swung through an arc and being inverted in preparation for the second sealing-in operation. Placing the assembly 40 on the non-tubulated mount which is sealed into the envelope after the envelope has been inverted thus avoids this potential manufacturing problem and insures that an amalgam of the desired composition will be formed within the completed lamp.

Another important feature of the preferred embodiment of the invention is the provision of a margin 45 (see Fig. 4) along each side edge of the assembly 40 that is initially free from amalgam-forming metal. As is shown more clearly in Fig. 7, this can readily be accomplished by using a sheet 44 of an amalgam-forming metal, such as indium, that has a width "S" which is smaller by a predetermined amount than the width "W" of the strips 42 and 43 of nickel wire cloth or other foraminous material that is used. The metal sheet 44 is approximately centered with respect to the cloth strips to provide margins 45 of a predetermined width "a" along each edge of the assembly 40 that is free from the amalgam-forming metal.

Experience has shown that when the amalgam-forming metal 44 extends to the edges of the cloth strips 42 and 43, it tends to collect in droplets along the edge of the assembly 40 when the lamp is handled in the factory while still hot. Occasionally, some of these droplets would be jarred loose from the assembly 40 while the lamp was still being processed or tested resulting in a loss of metal from the assembly and improper mercury-vapor pressure regulation. The provision of the metal-free margins 45 along both sides of the assembly 40 avoids this problem in that the amalgam-forming metal, even though it wets the cloth strips, takes a considerable time to migrate to the edges of the assembly. The margins, accordingly, provide a sort of "buffer" zone that retains the amalgam-forming metal on the assembly 40 during the subsequent fabrication and testing operations performed on the lamp. While the amalgam that is formed eventually migrates by capillary action to the edges of

the assembly 40, this occurs long after the lamp has been completed and has been in use and is thus no longer subjected to mechanical impacts that would tend to jar the amalgam loose from its support structure.

Specific Examples

In order to achieve proper control of the mercury-vapor pressure within the lamp and be practical from a manufacturing standpoint, the amalgam-retaining support structure of wire cloth or other foraminous material that is used must have the following characteristics:

(a) The support structure or assembly must expose a sufficient amount of the amalgam-forming metal to the mercury vapor within the lamp to establish dynamic equilibrium and optimum output within a short period of time, as for example within 5 to 10 minutes.

(b) The strips of foraminous material must provide a matrix having sufficient volume to contain the required amount of amalgam without the formation of teardrops;

(c) The openings in the foraminous material must be of a size such that the amalgam, when in a semi-liquid and liquid state, will fill the openings by capillary action.

(d) The foraminous strips must be fabricated from a material that is substantially inert with respect to both mercury and the amalgam-forming metal employed, and it must also be one which the amalgam will wet.

In addition, it is desirable that the relative dimensions of the foraminous strips and sheet of amalgam-forming metal be such that a margin that is initially devoid of metal will be provided along both edges of the completed assembly when the metal sheet is centrally located therein, as described above.

Experience has shown that all of the aforesaid requirements are met by fabricating the foraminous strips from a cloth woven from "Grade A" nickel wire approximately 0.009 inches in diameter and having 50 meshes per linear in each in each direction. The width of the openings in the cloth are thus approximately 0.011 inch and the open area of the cloth is about 30.3%. In the case of indium, two strips of nickel cloth 1-1/2 inches long and 3/8 of an inch wide, when combined with a strip of indium approximately 1/4 inch in width and 0.011 inch thick and the same length as the cloth strips, provided an assembly that contained approximately 500 milligrams of indium and a metal-free margin along each edge of the assembly approximately 1/16 inch wide. When this assembly was mounted on the step of a 96 inch 1500 milliampere fluorescent lamp having an envelope approximately 1-1/2 inches in diameter that was dosed with about 120 milligrams of mercury, an amalgam containing approximately 80% by weight of indium (approximately 88 atomic per cent indium) was formed within the lamp that maintained the mercury vapor pressure within the desired limits.

Since the mercury dosage required for satisfactory lamp life is proportional to the surface area of the bulb, a mercury-vapor control assembly constructed as described above from strips which are only half as long (3/4 inch) would be suitable for use in a 48 inch highly-loaded lamp of the same current rating containing approximately 60 milligrams of mercury.

For a 96 inch lamp of the aforsaid type, the minimum amounts of indium and mercury that can be used consistent with adequate lamp life are 222 milligrams and 100 milligrams, respectively. For a 48 inch lamp, the corresponding values are 50 milligrams of mercury and 111 milligrams of indium. In the case of a 72 inch lamp at least 166 milligrams of indium and 75 milligrams of mercury would be required.

Alternative Embodiments—Figs. 8 to 21

In Figs. 8 and 9, there is shown another form of lamp mount 30a and vapor control assembly 40a that are identical to those shown in Figs 2 and 4, respectively, except that the ends of the laminated assembly are cut at an acute angle relative to the longitudinal axis of the assembly rather than at right angles thereto. The ends of the assembly 40a are thus tapered in opposite directions and, when the assembly is mounted on the stem, the end edges are spaced from and extend parallel to one another along a line that is transverse to the stem axis, as shown in Fig. 8. This construction serves to prevent any droplets of amalgam, or amalgam-forming metal, that may form at the cut ends of the assembly from falling free when the lamp is held in a vertical, or tilted upright position, while the lamp is still hot. Since the cut end edges of the assembly lie one above the other throughout substantially their entire length, even when the lamp is held in a vertical position, any droplets that form along and fall from the uppermost edge will strike and be absorbed by the lowermost edge and thus be retained on the assembly.

In Fig. 10, there is shown another form of mount 30b wherein the collar-like vapor control assembly 40b is held in encircling but spaced apart relationship with the stem 31b by an L-shaped support wire 48 that is fastened to one of the lead wires adjacent to the stem press and to the assembly, as by welding to one of the metal cloth strips of the assembly. As shown more particularly in Fig. 11, this arrangement physically isolates the amalgam-containing assembly 40b from the stem 31b and minimizes the effect of variations in the ambient and stem temperature on the operating temperature of the amalgam.

If desired, the amalgam-containing assembly 40b may also be electrically isolated from the electrode 32b by utilizing an L-shaped support wire consisting of two segments 49 and 50 that are joined together by a glass insulater 51 (Fig. 12). In this case, the assembly 40b would not only be physically spaced from the stem tube but would be disposed in "electrically floating" relationship with respect to the electrode structure.

The same physical and electrical arrangement can also be obtained by providing a mount 30c having an L-shaped support wire 52 that is anchored in the stem press 37c, as shown in Fig. 13.

If desired, heat transfer to the vapor control assembly 40c may be further reduced by using a support wire 53 having an intermediate retroverted or looped portion 54, as illustrated in Fig. 14. This type of support would provide a longer heat path from the stem to the amalgam-containing assembly and thus serves to further isolate the amalgam from temperature variations induced in the stem by changes in the ambient temperature.

In Fig. 15 there is illustrated still another arrangement for mounting the amalgam-containing assembly in spaced relationship on the stem. According to this embodiment, the arcuate assembly 40d is held in the desired position by a resilient wire ring 55 that is clamped on the stem 31d and has a pair of laterally extending arms 56 that extend through and are interlocked with the assembly. As shown in Fig. 16, the laminated assembly 40d is provided with a pair of slot-like apertures 57 that are dimensioned and spaced to receive the hooked ends of the arms 56 and then hold them in such a position that the circular portion of the ring 55 is contracted and firmly locked in place around the stem 31d.

In Figs. 17 to 19 there is illustrated still another embodiment wherein the assembly-holding means includes bimetal elements 59 and 61 that are arranged to shift the position of the vapor control assembly 40e relative to the electrode 32e in response to variations in temperature within the lamp. The holding means in this case comprises a wire support 58 that is attached to the arcuate amalgam-containing assembly 40e and to one end of a generally U-shaped bimetallic element 59, the other end of which is connected by means of an arcuate support wire 60 that curves around the stem 31e (see Fig. 19) to the end of another U-shaped bimetallic element 61. The opposite end of this element is, in turn, secured to the upper part of the mount 30e by another support wire 62 that is embedded in the stem press 37e.

The aforesaid bimetallic elements 59 and 61 are adapted and arranged to form an elongated and movable heat-sensitive support member that shifts the assembly 40e toward and away from the electrode 32e along the stem 31e in response to temperature variations within the lamp induced by changes in the ambient temperature. Thus, when the ambient temperature is 120° F. for example, the assembly 40e will be spaced from the electrode 32e by a distance "$d_{maximum}$" (as indicated in Fig. 17) and will be automatically shifted toward the electrode and be spaced therefrom a distance "$d_{minimum}$" when the ambient temperature drops to a predetermined value, as for example 70° F. This arrangement, accordingly, automatically compensates for variations in the ambient temperature conditions and permits the operating temperature of the amalgam to be maintained within very close limits.

Another temperature-compensating arrangement is shown in Fig. 20 wherein the arcuate mercury-vapor control assembly 40f is held in spaced apart and encircling relationship with the stem 31f at a fixed distance from the electrode 32f by a relatively heavy support wire 64 that is attached to one end of the mount 30f and fastened, as by welding, to the assembly. An arcuate heat shield 65 is suspended between the assembly and electrode by a generally U-shaped bimetallic element 66 that is secured to the support wire 64. This bimetallic element is so arranged that at a preselected ambient temperature it exposes the amalgam-containing assembly 40f to the radiated and converted heat emanating from the electrode 32f and the discharge terminating thereon. This condition is illustrated by the solid line showing of the bimetallic element and shield in Fig. 20. However, when the ambient temperature increases, the bimetal flexes and shifts the shield into masking relationship with the assembly (as indicated by the dotted line showing of the bimetallic element and shield) thereby reducing the heating affect of the electrode on the assembly and maintaining the amalgam within the desired temperature range.

In Fig. 21 there is shown still another form of the invention wherein an amalgam-containing assembly 40g is supported in spaced apart relationship with the walls of the envelope 29 by a compressible wire clip 68 of generally U-shaped configuration that engages the envelope wall at a plurality of spaced points. The clip, when in relaxed condition, is slightly larger than the inner diameter of the envelope so that it is held in the desired position inside the lamp solely by the compressive force exerted by the envelope. The retaining clip is preferably of such configuration that the amalgam-containing assembly 40g is suspended at a location between the centre of the envelope and the envelope walls, such shown in Fig. 21, so as to avoid placing the amalgam in the main portion of the arc stream. If desired, more than

one amalgam-containing assembly may be attached to the clip, as indicated by the phantom showing of additional assemblies on the upstanding portions of the clip as viewed in Fig. 21.

In addition to the various holding arrangements described above, the amalgam-holding assembly may also be secured directly to the envelope wall at a preselected position along the bulb axis. This may be accomplished by providing a tab extension on the assembly, for example, and securing this to the envelope wall by a suitable cement that will not contaminate the lamp atmosphere.

Effects of Amalgam Composition and Location on Lamp Performance

Comparative lamp tests have shown that the compositon of the amalgam is critical with regard to both the mechanical design and the performance of the lamp. In order for the lamp to be commercially practical on both counts, the amalagam must be retained at the desired location within the lamp even though the amalgam may be converted into a liquid at the temperatures that prevail within the lamp when the latter is energized. On the other hand, when the lamp is not energized the amalgam must be sufficiently rigid or "stiff" to remain on or within the support structure on which it is placed so that the lamp can be handled and shipped without dislodging the amalgam.

In the case of an indium-mercury amalgam, for example, it has been discovered that the amount of indium in the amalgam must be maintained within the range of about 80 to about 95 atomic per cent. As shown in the phase diagram illustrated in Fig. 22, an amalgam containing this amount of indium remains in either the solid or liquid-solid phase over a temperature range from −4° F. and below to at least about 122° F. Thus, if an amalgam of this composition is placed within the lamp it will remain in a substantially solid state and will not be jarred loose from its support structure while the lamp is being handled during manufacture or shipment. The aforesaid range of temperature is indicated by the lower hatched region 70 in the graph and is identified as the "non-operating range".

An indium-mercury amalgam containing from about 80 to 95 atomic per cent indium and operating at temperatures from about 122° F. to 266° F. will tend to liquify. However, even when in a liquid state such an amalgam will be retained on a suitably designed foraminous support structure, such as the type described previously. Thus, the amalgam will be held in the proper location within the lamp while the latter is operated in its fixture. This temperature range is indicated by the upper hatched region 72 on the graph and is identified as the "operating range". As will be noted, most of the combinations of indium-mercury amalgam compositions and operating temperatures provide an amalgam that remains in either the solid or liquid-solid state.

While there is a considerable overlap of the aforesaid ranges, as indicated by the cross-hatched region 74 on the graph, it will be appreciated that an amalgam that is sufficiently rich in indium can be retained in a properly designed holding assembly over a range of temperatures broad enough to enable the lamp to be operated under an extremely wide range of ambient temperatures and power loadings.

This is indicated by the graph shown in Fig. 23 wherein the variation in the operating temperature of an amalgam located on the bulb wall and on the stem versus ambient temperature is shown for a typical 96 inch highly-loaded (1500 ma) lamp operated bare in still air. The temperature of the amalgam is much higher when it is located on the stem (curve 76) rather than the bulb wall (curve 78). However, since the two curves are substantially parallel, it is apparent the temperature of the amalgam is effected in substantially the same manner by changes in ambient temperature regardless of the location of the amalgam within the lamp. Thus, at an ambient temperature of 110° F. the operating temperature of the amalgam when located on the stem approximately 40 millimeters from the electrode will be about 230° F. in this particular type of lamp, (as indicated by curve 76), which is well within the "operating range" referred to above and indicated by the hatched region 72 of Fig. 22. In addition, the operating temperature of the amalgam on the stem can be varied over a considerable range (for example down to about 200° F. at the aforesaid ambient temperature of 110° F.) simply by shifting its position on the stem and increasing or decreasing the distance between the amalgam and the electrode. The degree of temperature control afforded by adjusting the position of the amalgam on the lamp stem is indicated by the shaded region 79 in Fig. 23, which region straddles the curve 76 and spans a range of about 40° F. This temperature difference was obtained by varying the amalgam-electrode spacing over a range of approximately 8 millimeters, that is, from 34 millimeters to 42 millimeters. The operating temperature of the amalgam can be controlled over a wider range by increasing the amalgam-electrode spacing a corresponding amount, and by using a longer stem if necessary.

As indicated by the dotted line portions of the curve 76 and shaded region 79, the amalgam, when placed on the stem 34 millimeters from the electrode, will not reach a temperature of 266° F. until the ambient temperature is increased to about 140° F.

On the basis of this extrapolated portion of the graph, satisfactory control of the mercury vapor pressure can be maintained at ambient temperatures ranging from about 40° F. to 140° F. even when the amalgam-electrode spacing is quite small.

The marked improvement in the per cent brightness maintained at various ambient temperatures by using an indium-rich amalgam is indicated in the graph shown in Fig. 24. The curve 80 represents the change in the light output exhibited by a conventional highly-loaded lamp having end chambers when the lamp is operated at various ambient temperatures. As will be noted, the conventional lamp had a peak output of an ambient temperature of about 70° F. (still air) and dropped to 90% brightness at ambient temperatures of approximately 48° F. and 98° F. The conventional lamp thus maintained 90% of its peak output over an ambient temperature range of about 50° F.

In contrast, the corresponding curve 82 of a highly-loaded lamp of the same type and dimensions containing an amalgam having approximately 87 atomic per cent indium shows that this lamp had a peak output at about 80° F. ambient (still air) and maintained 90% of its peak output from about 42° F. to about 130° F. ambient, or over a range of 88° F. The brightness versus ambient temperature curve 82 of the indium-mercury amalgam lamp is thus much flatter and wider than the corresponding curve 80 for the conventional lamp utilizing end chambers and condensed mercury as the vapor-pressure control center. In order to maintain the brightness at 90% of the peak the mercury vapor pressure must be maintained between about 3 to 14 microns. It will accordingly be apparent that the indium-mercury amalgam maintained this pressure over a wider range of ambient temperatures and markedly improved the lamp performance under varying ambient temperature conditions, as is indicated by the relative sizes of the hatched and cross-hatched areas under the respective curves in Fig. 24.

The use of an indium-mecury amalgam containing at least 80 atomic per cent indium affords an additional advantage in that the brightness of the lamp is less affected by changes in ambient temperature as the atomic per cent of indium in the amalgam is increased above this value. This is indicated by the curves 83, 84 and 85 in Fig. 25 which illustrate the manner in which the brightness of identical lamps, designed to peak at the same ambient temperature A°, varied as the atomic per cent of indium in the amalgam was increased from 80% to 87% and finally 92.5%, respectively. As is indicated the lamp containing amalgam having 92.5 atomic per cent indium was much flatter and maintained 95% brightness over a significantly wider range of ambient temperature (about ±35° F.) than any of the other lamps. Thus, from an operational standpoint it is preferred that the atomic per cent of indium in the amalgam be made as high as practical.

This broadening effect of indium-mercury amalgam on the output versus ambient temperature characteristic of the lamp is not only unique but is extremely advantageous in that the amalgam becomes less liquid as the indium content is increased (see Fig. 22) and will thus exhibit less of a tendency to become dislodged from the retaining assembly when the lamp is operated.

The flexibility of lamp design afforded by the present invention is illustrated in Fig. 26 which illustrates how the peak output versus ambient temperature characteristics of a given lamp can be shifted simply by varying the spacing between the amalgam and the electrode. As indicated by the curve 86, with an electrode-amalgam spacing of 34 millimeters the lamp peaked at an ambient temperature of about 75° F. (still air), whereas peak output occurred at about 97° F. ambient with a spacing of 38 millimeters (curve 87) and at about 115° F. ambient when the spacing was increased to 42 millimeters (curve 88). The lamps on which these curves are based were 48 inch lamps having a current rating of 1500 ma and an indium-mercury amalgam containing 85 atomic per cent indium. Thus, by properly correlating the amalgam composition and the amalgam-electrode spacing, it will be apparent that lamps can be designed to peak at the particular ambient temperature desired within the range of operating temperatures usually encountered in the application of such lamps. As indicated by this family of curves, 90% of peak brightness can be obtained at ambient temperatures ranging from about 40° F. to 160° F. by properly adjusting the amalgam-electrode spacing.

The marked improvement in lamp performance obtained by using an indium-rich amalgam in accordance with this invention is also illustrated by the graph shown in Fig. 27. In the graph, the ambient temperature range within which 95% of peak brightness is maintained is plotted against the atomic per cent indium present in the amalgam. As indicated by point E, a conventional 48 inch highly-loaded fluorescent lamp having end chambers and pure memory (0 atomic % In) maintained 95% of its peak brightness over an ambient temperature range of 25° F. The corresponding value for a conventional 96 inch lamp having end chambers is indicated by point J and is approximately 33° F. A 96 inch lamp employing a cooled region and condensed mercury as the vapor-pressure control center maintained 95% of its peak output over ambient temperature range of 31° F. (point K on the graph).

In contrast, highly loaded 96 inch lamps containing an In-Hg amalgam with 80 atomic

per cent, 87 atomic per cent and 92.5 atomic per cent indium sustained 95% of peak output over an ambient temperature range of 42° F., 55° F., and 67° F., respectively, (points Ia, Ib, and Ic). As indicated by the upward slope of the curve 90 drawn through these points, the brightness is maintained at 95% of the peak over progressively wider ranges of ambient temperature as the amount of indium in the amalagam is increased. Hence, a highly-loaded lamp capable of maintaining its output over a much wider range of ambient temperatures than was heretofore possible with a condensed-mercury control center can be designed by properly adjusting the indium content of the amalgam.

It will be appreciated from the foregoing that the objects of the invention have been achieved insofar as a novel and very convenient means for controlling the mercury vapor pressure within a highly-loaded fluorescent lamp or other gaseous discharge device has been provided. The amalgam-retaining structures are such that they can be readily fabricated and assembled with the lamp components without interfering in any way with the regular sequence of lamp-making operations.

While a number of lamp embodiments and a preferred method of fabricating an amalgam-retaining assembly have been described, it is to be understood that various modifications can be made without departing from the scope of the invention.

WHAT WE CLAIM IS:—

1. A low pressure mercury vapor discharge lamp comprising a sealed radiation transmitting envelope, a pair of spaced electrodes mounted in said envelope, a foraminous support structure supported within said envelope at a predetermined location spaced from said electrodes and an amalgam of a metal with mercury anchored to said support structure for controlling the mercury vapor pressure within said envelope during operation of said lamp, said support structure consisting of a material which is wetted by said amalgam in the liquid state thereof thereby to retain said amalgam anchored to said support structure.

2. A lamp as claimed in claim 1, wherein said amalgam is substantially in the solid state at temperatures up to about 40° C.

3. A lamp as claimed in claims 1 and 2, wherein the location of said amalgam is such that its temperature remains below about 130° C when the lamp is operated at an ambient temperature of from about 4° C. to 71° C. at its rated power loading.

4. A lamp as claimed in claim 1, 2 or 3, wherein the metal of said amalgam comprises at least one of the metals tin, thallium, indium, or alloys thereof.

5. A lamp as claimed in any of claims 1 to 4, wherein said amalgam extends over a considerable portion of said support structure and at least partly fills the openings thereof.

6. A lamp as claimed in any of claims 1 to 5, wherein said support structure comprises a piece of metal wire cloth.

7. A lamp as claimed in any of claims 1 to 6, wherein said support structure comprises a pair of foraminous members, between which a layer of a relatively soft metal is sandwiched, said metal being capable of combinding with mercury to form an amalgam that wets said members.

8. A lamp as claimed in claim 7, wherein said members are partly embedded in said layer of amalgam-forming metal and are held in assembled relationship therewith solely by said metal.

9. A lamp as claimed in claim 7 or 8, wherein said members comprise a pair of generally rectangular strips of metal wire cloth, between which a sheet of said amalgam forming metal is sandwiched.

10. A lamp as claimed in claim 9, where in said sheet of amalgam-forming metal has a smaller width dimension than said wire cloth strips and is spaced inwardly from the side edges thereof so as to provide a region along both sides of the assembly that is devoid of said metal.

11. A lamp as claimed in any of the claims 1 to 10, and comprising a vitreous stem sealed to and extending inwardly from each end of the lamp envelope, a pair of lead wires sealed through each of said stems and extending therefrom into said envelope, and an electrode attached to the inwardly projecting end segments of each pair of lead wires, wherein the support structure carrying the amalgam and forming therewith a vapor control assembly, is held by one of said stems at a predetermined location between the respective electrode and end of said envelope.

12. A lamp as claimed in claim 11, wherein said vapor control assembly is arcuate and holding means are provided which hold said arcuate assembly in encircling relationship with said stem at a location such that said assembly is spaced a predetermined distance from the transverse plane that passes through the portions of said lead wire segments that are fastened to said electrode.

13. A lamp as claimed in claim 12, wherein said holding means comprise a resilient annular member that overlies said arcuate assembly and firmly clamps it around said stem.

14. A lamp as claimed in claim 12, wherein the length of said arcuate assembly is slightly less than the circumference of said stem so that the ends of the assembly are thus proximate to but spaced from one another, and the said proximate ends of the assembly are tapered in opposite directions and disposed in generally parallel relationship

with a line that extends transverse to the stem axis.

15. A lamp as claimed in claim 12, wherein said holding means comprises a support wire that is fastened to one of said lead wires and to said assembly and holds the latter in encircling but spaced apart relationship with the stem.

16. A lamp as claimed in claim 15, wherein said support wire consists of two wire segments that are joined together by an insulator which electrically isolates the vapour-control assembly from the lead wire to which it is attached.

17. A lamp as claimed in claim 12, wherein said holding means comprise a support wire that is anchored in the stem press and is fastened to and holds said assembly in encircling but spaced apart relationship with the stem.

18. A lamp as claimed in claim 12, wherein said holding means comprises a support wire having one end anchored in said stem press and its opposite end fastened to said assembly, and said support wire has a retroverted intermediate portion of such configuration that said assembly is disposed in encircling but spaced apart relationship with said stem.

19. A lamp as claimed in claim 12, wherein said holding means comprise a resilient annular member that is clamped in encircling relationship on said stem and has a laterally extending leg that is attached to said arcuate assembly and supports it in encircling but spaced apart relationship with said stem.

20. A lamp as claimed in claim 12, wherein said holding means comprise a plurality of wires and a pair of bimetallic elements that are joined together and constitute an elongated heat-sensitive support member having one end secured to said mount structure and its opposite end fastened to said assembly, said support member having a configuration such that said assembly is disposed in encircling but spaced apart relationship with said stem, and said bimetallic elements being arranged and operable in response to temperature variations within said lamp to move the vapor-control assembly along said stem toward and away from the electrode and thereby minimize the effect of such temperature variations in the amalgam carried by said assembly.

21. A lamp as claimed in claim 12, wherein said holding means comprise a support wire having one end fastened to said mount and its opposite end fastened to said assembly, and a shield member that is suspended between said assembly and the electrode by a bimetallic element that is fastened to said support wire, said bimetallic element being arranged and operable in response to variations in temperature within said lamp to move the shield member into and out of masking relationship with said assembly.

22. A lamp as claimed in any of the claims 1 to 10, wherein said support structure comprises a resilient clip that engages the inner surface of the lamp envelope at spaced points and is retained within said envelope at a predetermined location along its axis solely by the compressive force exerted on the clip by said envelope.

23. A lamp as claimed in any of the preceding claims, wherein the metal of said amalgam comprises indium in such an amount that said indium combines with substantially all of the mercury when the lamp is deenergized and forms an amalgam containing at least 80 atomic per cent indium.

24. A lamp as claimed in claim 23, wherein the amalgam resulting from the combination of said mercury and indium contains from about 80 to about 95 atomic per cent indium.

25. A lamp as claimed in claim 24 and having a length of approximately 48 inches and a diameter of $1\frac{1}{2}$ inches characterized in that it contains at least 50 milligrams of mercury and at least 111 milligrams of indium.

26. A lamp as claimed in claim 24 and having a length of approximately 72 inches and a diameter of $1\frac{1}{2}$ inches characterized in that it contains at least 75 milligrams of mercury and at least 166 milligrams of indium.

27. A lamp as claimed in claim 24 and having a length of approximately 96 inches and a diameter of $1\frac{1}{2}$ inches characterized in that it contains at least 100 milligrams of mercury and at least 222 milligrams of indium.

28. A low-pressure mercury-vapor discharge lamp, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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Agents for the Applicants.

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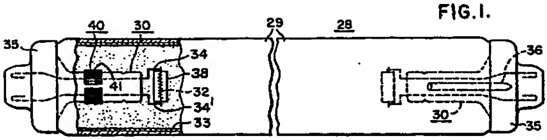
Sheet 1

FIG. 1.



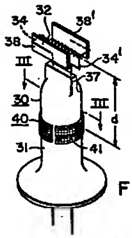


FIG. 2.

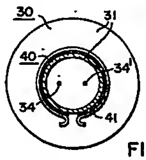
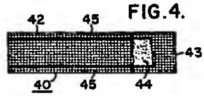


FIG. 3.

FIG. 4.



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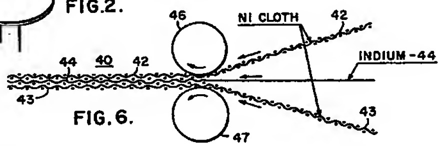
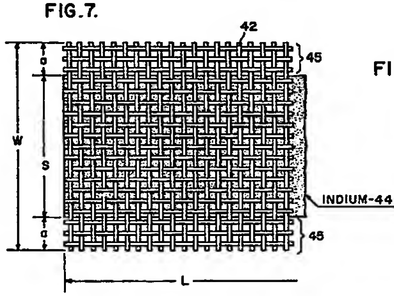


FIG. 6.

FIG. 7.



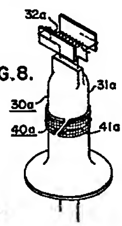
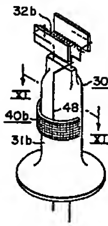


FIG. 8.

FIG.10.



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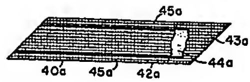

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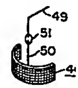

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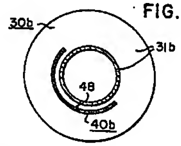

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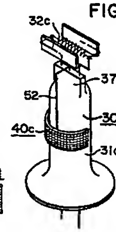
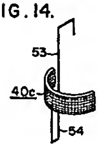


FIG.14.



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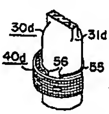

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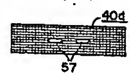


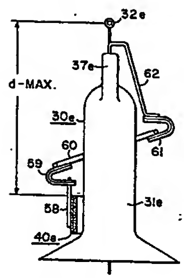
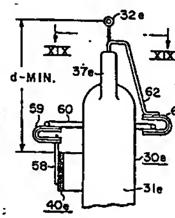


FIG.17.

FIG.18.



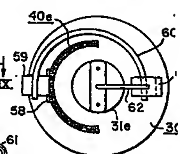


FIG.1

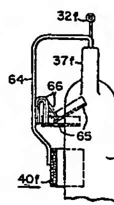


FIG.2

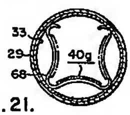


FIG.21.

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FIG. 12.

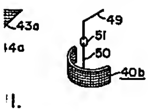
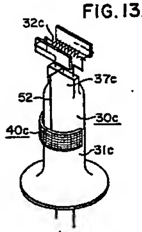


FIG. 13.



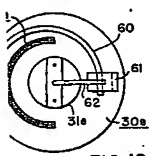
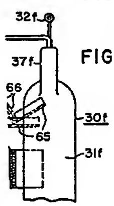


FIG. 19.



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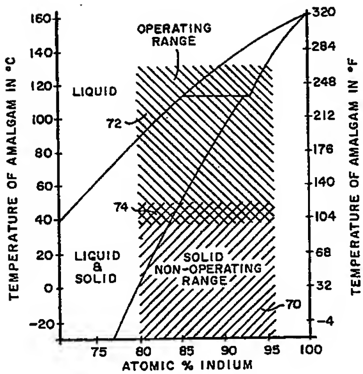

FIG. 22.

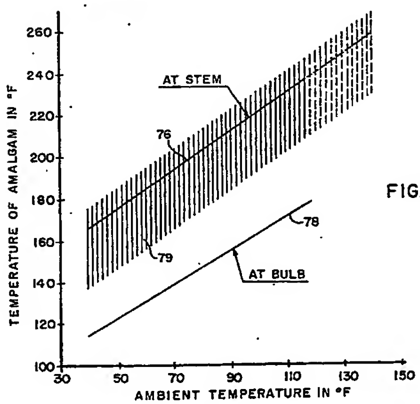

FIG. 23.

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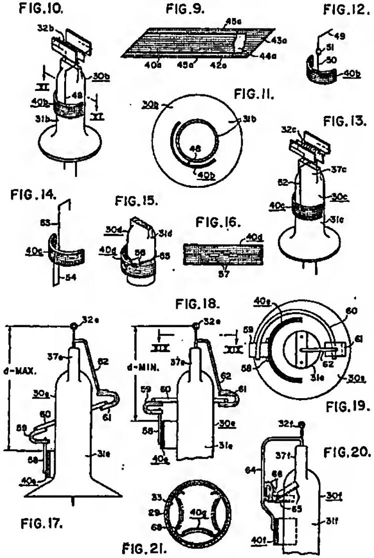
FIG.10. FIG.9. FIG.12. FIG.11. FIG.13. FIG.14. FIG.15. FIG.16. FIG.17. FIG.18. FIG.19. FIG.20. FIG.21.



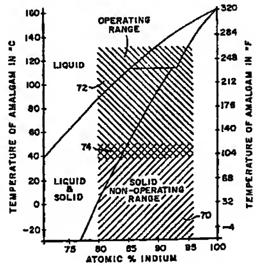


FIG.22.

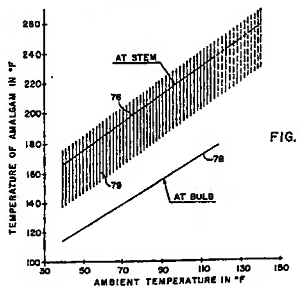
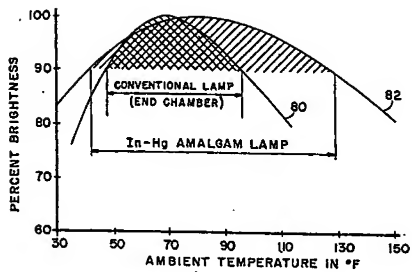


FIG.23.

FIG. 24.


100
90
80
70
60
PERCENT BRIGHTNESS
CONVENTIONAL LAMP
(END CHAMBER)
In-Hg AMALGAM LAMP
80
82
30
50
70
90
110
130
150
AMBIENT TEMPERATURE IN °F

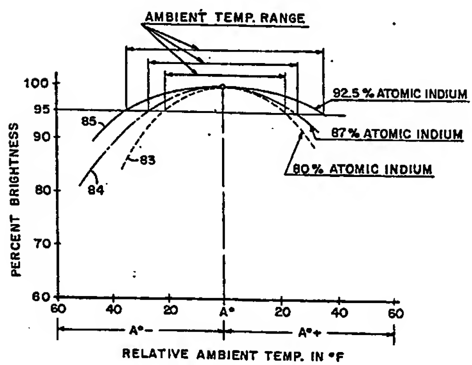
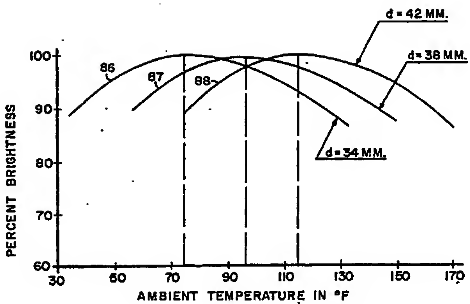
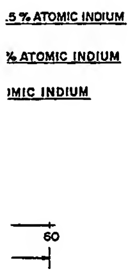

AMBIENT TEMP. RANGE
100
95
90
80
70
60
PERCENT BRIGHTNESS
85
83
84
92.5 % ATOMIC INDIUM
87 % ATOMIC INDIUM
80 % ATOMIC INDIUM
60
40
20
A°
20
40
60
A°−
A°+
RELATIVE AMBIENT TEMP. IN °F

FIG. 25.

FIG. 24.

FIG. 26.





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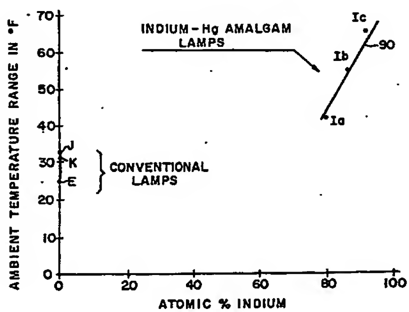
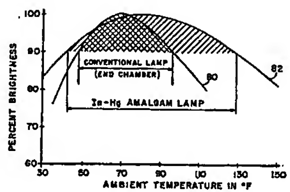


FIG. 27.

FIG. 24.



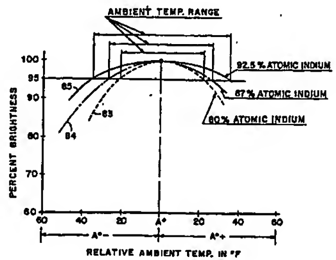
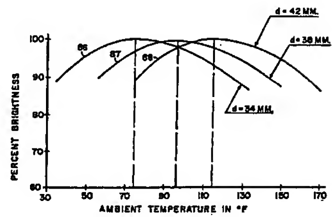


FIG. 25.

FIG. 26.



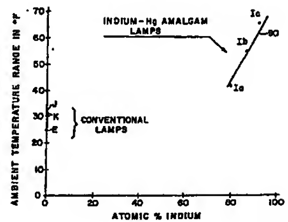


FIG. 27.